https://doi.org/10.2352/ISSN.2470-1173.2021.2.SDA-100

Sourcing and Qualifying Passive Polarised 3D TVs

Andrew J. Woods; Curtin University; Perth, Western Australia, Australia.

Abstract

Millions of Stereoscopic 3D capable TVs were sold into the consumer market from 2007 through to 2016. A wide range of display technologies were supported including rear-projection DLP, Plasma, LCD and OLED. Some displays supported the Active 3D method using liquid-crystal shutter glasses, and some displays supported the Passive 3D method using circularly polarised 3D glasses. Displays supporting Full-HD and Ultra-HD (4K) resolution were available in sizes ranging from 32" to 86" diagonal. Unfortunately display manufacturers eventually changed their focus to promoting other display technologies and 2016 was the last year that new 3D TVs were made for the consumer market. Fortunately, there are still millions of 3D displays available through the second-hand-market, however it can be difficult to know which displays have 3D display support. This paper will provide a listing of specifically Passive 3D TVs manufactured by LG, however it has been our experience that the 3D quality varied considerably from one display to another hence it is necessary to qualify the quality of the 3D available on these displays using a testing technique that will be described in the paper.

Introduction

The period 2007 to 2016 were bumper years for 3D TV production. Millions of 3D TVs sold into the consumer market over this period [1] and over a hundred different 3D TV models available from multiple manufacturers in stores around the world. Multiple display technologies were used to deliver high-quality 3D images including rear-projection DLP (Digital Light Projection) [2], Plasma [3], LCD (Liquid Crystal Display) [4] and OLED (Organic Light Emitting Diode). 3D TVs deliver a 3D image to viewers using either the Passive 3D method (users wear passive polarized 3D glasses) or the Active 3D method (users wear liquid-crystal shutter glasses which switch in synchronisation with alternately displayed left and right 3D images on the display). The displays were big, bright, and high-resolution. There was plentiful supply and there were affordable prices. BUT… 2016 was the last year that 3DTVs were manufactured and sold by the mainstream manufacturers. 3D projectors remain available new in market, but not 3D TVs.

3D display remains a requirement in many consumer and commercial applications. Unfortunately, the only current source of large-screen 3D TV displays is the second-hand market.

This paper will primarily focus on the availability of passive 3D TVs, of which the leading manufacturer of this style of 3D TV was LG.

Background

Passive 3D displays use a technique which goes by a few different names: Spatially Multiplexed Polarisation, Film Patterned Retarder (FPR), or “Cinema 3D” – the latter two names being used predominantly by LG.

Passive 3D displays work by the application of a micropolarizer (µPol) array to the front surface of the display – typically an LCD or an OLED as illustrated in Figure 1. The µPol array is an optical film which has horizontal strips of alternating optical performance which results in alternate rows of the display being polarised with complementary polarisation (usually circular polarisation). When the user wears the appropriate 3D glasses, one eye sees the odd numbered rows of the display and the other eye sees the even numbered rows of the display. The first published paper describing spatially multiplexed polarisation 3D displays was by Faris in 1994. [5]

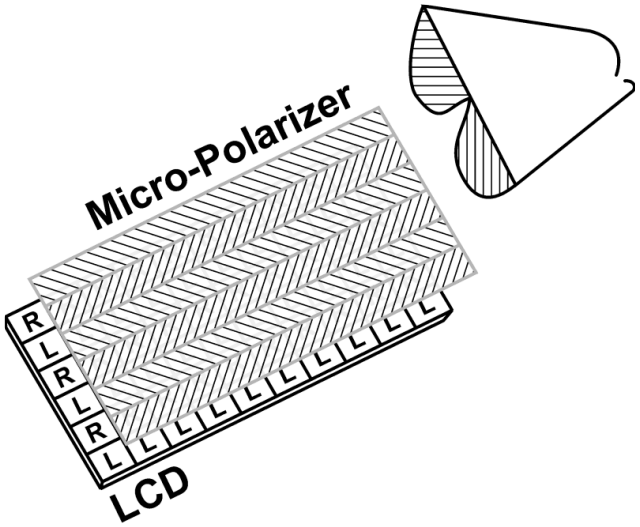


Figure 1. Optical layout of a micropolarised (Passive 3D) stereoscopic display. Diagram based on Faris [5].

Passive 3D displays have the advantage that the passive polarised 3D glasses used with these displays are lightweight, comfortable, inexpensive and readily available. The LG passive 3D displays use the same glasses used in RealD 3D cinema theatres so the glasses can be obtained very cheaply. But, one limitation of these displays is that in 3D mode each eye sees a half vertical resolution image. For a Full-High-Definition (Full-HD) passive polarised 3D display (1920×1080 pixel resolution), in 3D mode each eye will receive an image 1920×540 pixels in resolution (the same width, but half the height of Full-HD).

In 2012 LG started releasing “4K” or Ultra-HD resolution “Cinema 3D” TVs. These displays had four times the number of display pixels as a Full-HD display. In the consumer market, 4K resolution equates to a resolution of 3840×2160 pixels. This resolution results in 8.3 million total display pixels, whereas a Full-HD display only has 2.1 million pixels.

By 2016, LG’s entire line-up of 3D TVs were all 4K. The big advantage of a 4K passive 3D display is that it allows Full-

HD resolution per eye in 3D mode. The resolution per eye is 3840×1080, which is the same vertical resolution as Full-HD but twice the horizontal resolution of Full-HD. Importantly Blu-ray 3D discs provide Full-HD resolution to both eyes, and 4K passive 3D displays allow this full resolution to be displayed to both eyes without limitation. In contrast, a 2K passive 3D display can only display half the vertical resolution of Full-HD to each eye.

It is often mentioned that stereoscopic displays provide a super-resolution effect, in effect providing a resolution boost over the native resolution provided to each eye. The belief is that stereoscopic viewing of half-vertical resolution Full-HD 3D content can result in a perceived total resolution close to Full-HD resolution. The extension of this is that stereoscopic viewing of Full-HD 3D content where both eyes each receive a Full-HD resolution image also has a super-resolution effect meaning the total perceived image resolution is even higher than Full-HD. It would be good to find a study which has studied and documented this effect. If you know of such a study, please let me know.

Sources of 4K Passive Polarised 3D Displays

During the 3DTV boom of 2012 to 2016, LG was the dominant source of passive polarised 3D TVs, and particularly 4K passive polarised 3D TVs.

LG Passive 3D 4K TVs

Table 1 provides a listing of all LG Passive 3D 4K TVs released into the consumer market from 2012 to 2016 – the period that passive 3D TVs were sold by LG. Over this period LG released 4K 3D TVs 51 different models with 9 different panel sizes, and using both OLED and LCD technologies. The smallest 4K 3D TV was a 49” (~1.2 m) diagonal model, and the largest was a massive 98” (~2.5 m) diagonal. There were four models larger than 80” (2 m) diagonal.

The listing shown in Table 1 are the passive 3D 4K TV model numbers as sold into the USA market. LG model numbers in other regions did vary slightly from this format. Not all sizes were available in every region.

In addition to the LG models, there were also a few consumer 3D TV models from Sony and Toshiba to offer the combination of 4K resolution and passive 3D capability. In 2013, Toshiba offered the L9300U series and the Sony sold the X900A series, and in 2014 the Sony XBR-X850B series offered passive 3D. [6] I have not tested any of these models so cannot comment on their 3D performance.

Regrettably, the 4K 3D TVs listed here are no longer available new, but it’s important to remember there have been millions of 3D TVs sold into the consumer market and they do routinely show up on second-hand sites such as eBay, Craigslist, Gumtree, and others.

Please note that LG also supplied Full-HD passive 3D displays but they are not listed in this paper because the 3D quality of 4K passive 3D displays is so much better than Full-HD passive 3D displays, but are listed elsewhere. [7]

Table 1: Listing of LG Passive 3D 4K TV models sold into the USA market identifying sizes, model numbers and technology (OLED or LCD)

2016 LG OLED				
77" OLED77G6P	65" OLED65G6P			
65" OLED65E6P	55" OLED55E6P			
65" OLED65C6P	55" OLED55C6P			
2016 LG LCD				
86" 86UH9500	79" 79UH9500	65" 65UH9500	55" 55UH9500	
75" 75UH8500	65" 65UH8500	60" 60UH8500	55" 55UH8500	49" 49UH8500
2015 LG OLED				
77” 77EG9900	65" 65EF9800			
65" 65EG9600	55" 55EG9600			
65” 65EF9500	55" 55EF9500			
55" 55EG9200				
2015 LG LCD				
79" 79UF9500	65" 65UF9500	55" 55UF9500		
79" 79UG880V				
65" 65UG870V	55" 55UG870V			
65" 65UF860V	55" 55UF860V	49" 49UF850V		
65" 65UF8500	60" 60UF8500	55" 55UF850V		
2014 LG OLED				
77” 77EC9800				
65” 65EC9700				
2014 LG LCD				
98” 98UB9800	84” 84UB9800	79” 79UB9800	65” 65UB9800	
65” 65UB9500	55” 55UB9500			
55” 55UB9500	49” 49UB9500			
55” 55UB830V	49” 49UB830V			
2013 LG LCD				
65" 65LA9700	55" 55LA9700			
65” 55LA9650	55” 55LA9650			
2012 LG LCD				
84" 84LM9600				

Qualifying Passive 3D Displays

Unfortunately, in our experience, some passive 3D TVs exhibit significant crosstalk problems – that is, the image from the left eye leaks into the view for the right eye, and vice-versa – visible as parts of the screen which have a ghost like appearance. [8, 9] In this instance the crosstalk is likely due to three possible problems with the micropolariser filter: (1) problems with the optical quality of the micropolariser filter that means the circularly polarised output is not complete, (2) problems with the geometry of the polarising strips in the micropolariser filter, and (3) problems with the application of the micropolariser filter such that the micropolariser rows don’t align correctly with the rows of pixels of the display. The result is that there can be areas of the screen that exhibit excessive amounts of stereoscopic crosstalk, hence it is important to qualify or test candidate displays for correct 3D performance before purchase. A display that has excessive amounts of crosstalk will be perfectly fine for the display of 2D content, but for 3D content it could be unusable. This type of fault cannot be corrected by the consumer or a repair centre. The only way to fix the fault would be to replace the display panel, which may not be possible due to limited availability of spare parts. In order to qualify or test the 3D performance of a particular passive 3D display, a simple black-white test pattern can be used – as discussed in the next section.

The Black-White Test Pattern

The black-white test pattern is a very simple concept – a black image is sent to the left eye, and a white image is sent the right eye, or vice versa. The purpose of having one eye shown a black image is that it makes it much easier to see how much light is leaking from the one channel (the bright eye) into the opposite channel (the dark eye) in the form of crosstalk. [8, 9]

Most passive polarised 3D TVs allow a video signal to be sent to the TV in top-bottom (also known as over-under) format, and the display electronics of the TV convert this to the row-interleaved 3D format which corresponds with the arrangement of the micropolariser array. As shown in Figure 2 below, the top half of the input image is black and the bottom half of the input image is white. The display converts this to alternating rows of black and white pixels on the display. When passive 3D glasses are worn by the user, the ideal result will be that the right eye sees full black and the left eye sees full white (or vice versa depending upon the 3D polarity chosen) – as illustrated in Figure 3.

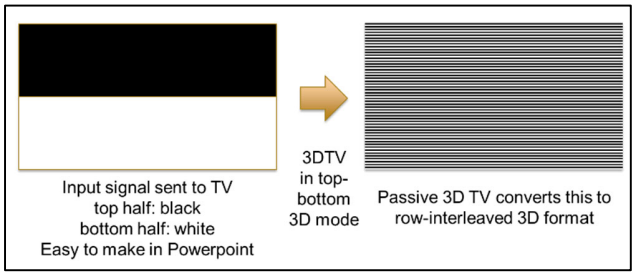


Figure 2. Illustration of a black-white test signal input in top-bottom / over-under 3D format and its conversion to row-interleaved 3D format

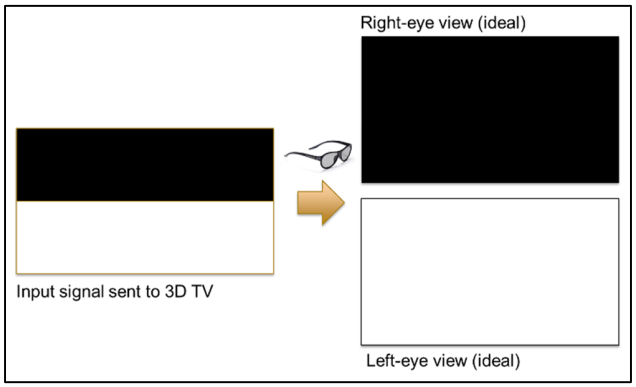


Figure 3. Illustration of an ideal result of viewing a black-white test signal on a passive 3D TV.

Unfortunately, almost all 3D displays exhibit a certain amount of image crosstalk whereby some of the left eye image leaks into the right eye view and vice versa. [8, 9] The mechanism by which this occurs varies between different stereoscopic display technologies. [8, 9]

With micro-polarised passive 3D TVs, crosstalk is usually due to two things: (1) optical quality of the micropolariser filter array and the polarised 3D glasses, and (2) alignment of the micro-polariser layer to the pixels on the 3D TV. Figure 4 below shows an illustration of a good result. There is a faint blueish glow in the black eye, but the level is low across all of the display surface.

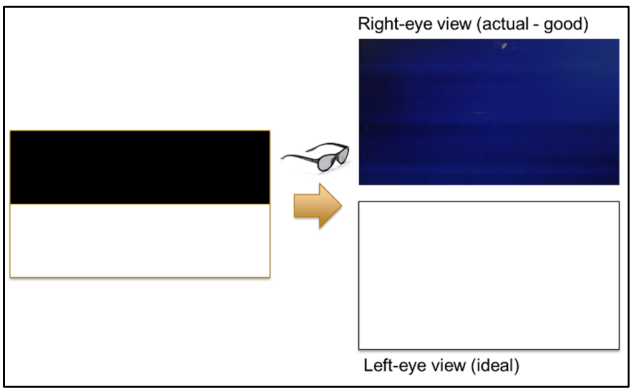


Figure 4. Illustration of a good actual result of viewing a black-white test signal on a passive 3D TV.

Unfortunately some micropolarised passive 3D displays exhibit a poor optical performance – as illustrated in Figure 5a. On this particular display there is a noticable amount of crosstalk visible at the bottom and top of the display – as visible with white areas on the bottom and top of the display. In this instance the crosstalk is due to a misalignment of the micropolariser with the pixels of the display. We know that because if the viewing height is changed (i.e. the observer stands higher or lower), the pattern of the crosstalk changes, and it changes consistent with that height change as shown in Figure 5b.

Figure 5a. Illustration of a poor actual result of viewing the black channel of a black-white test pattern on a passive 3D TV.

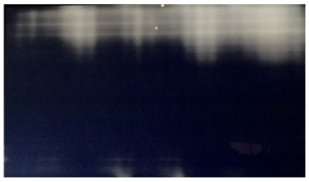


Figure 5b. Illustration of a poor actual result of viewing the black channel of a black-white test pattern on the same passive 3D TV but from a different viewing height.

Previously we have reported on the use of a different crosstalk test pattern [10] as illustrated in Figure 6. This test pattern was useful for measuring (within some technical limits) the amount of crosstalk in a stereoscopic display, where that crosstalk is consistent across the whole of the display. However, this test pattern cannot be used for stereoscopic displays where the crosstalk is not consistent across the whole display surface.

The 'micropolariser misalignment' crosstalk on the passive polarised 3D displays we have just discussed is not consistent across the entire display surface so in this instance this test pattern cannot be used, and the black-white crosstalk test pattern is the one that should be used.

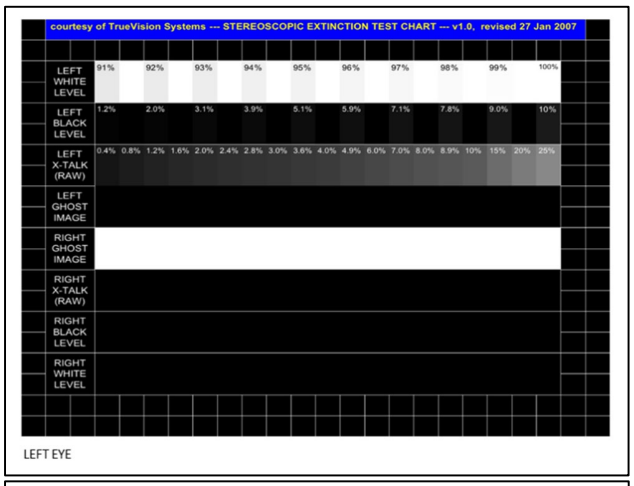


Figure 6. Whole of display custom crosstalk test pattern from Weissman [10].

Discussion

In addition to the aforementioned large-screen passive polarised 3D displays, passive 3D displays are also available in a couple of additional categories.

Passive 3D Monitors

There are also some smaller size passive 3D displays for computer monitor use, such as the Asus VG27AH 27" Passive 3D Monitor, but those are not listed in detail in this particular paper due to their smaller size.

Medical Passive 3D Displays

Some passive polarised 3DTVs are available new for the medical applications market - particularly for 3D endoscopy. Unfortunately, these screens are smaller than the large screen 3D TVs that were available in the consumer market, and the pricing is higher than was available for the consumer 3DTVs – particularly due to the lower manufacturing volumes and also additional medical certification requirements.

Medical category passive 3D displays include:

Sony:
55” 4K LMD-X550MT
31” 4K LMD-X310MT
24” Full-HD LMD-2451MT
www.pro.sony.com

NDS:
32” 4K
www.ndssi.com

EIZO CuratOR:
26” Full-HD Eizo EX2620-3D
www.eizo-or.com

For the interested reader, an extensive list of 3D displays, passive 3D and other technologies is available online. [7]

Conclusion

Although 3D TVs are no longer available new in the consumer market, many millions of high-quality large-screen 3D TVs remain available in the second-hand market.

4K passive polarised 3D TVs offer many advantages over other 3D display technologies, including light-weight battery-free 3D glasses, Full-HD 3D resolution, and large colourful bright and sharp 3D images.

Unfortunately, some passive 3D displays have micropolariser misalignment problems and exhibit excessive crosstalk in some parts of the screen. Hence second-hand passive 3D TVs should be tested before purchase using the testing procedure described.

Despite a contraction of the 3D display market from the highs of the period 2006 to 2017, 3D display remains an important capability with high impact, particularly in the education, academic and industry sectors.

References

[1] Rave, “DisplaySearch Says 21 Million 3D TVs Were Sold in 2011,” 12 March 2012. [Online]. Available: https://www.ravepubs.com/displaysearch-says-21-million-3d-tvs-were-sold-in-2011/. [Accessed 20 January 2021].

[2] A. Woods and T. Rourke, “The compatibility of consumer DLP projectors with time-sequential stereoscopic 3D visualisation,” in *presented at Stereoscopic Displays and Applications XVIII, published in Stereoscopic Displays and Virtual Reality Systems XIV, Proceedings of IS&T/SPIE Electronic Imaging Vol. 6490*, San Jose, California, 2007.

[3] A. J. Woods and K. S. Karvinen, “The compatibility of consumer plasma displays with time-sequential stereoscopic 3D visualisation,” in *Stereoscopic Displays and Applications XIX, Proceedings of SPIE Vol. 6803*, San Jose, California, 2008.

[4] A. Woods, “3-D Displays in the Home,” *Information Display,* pp. 8-12, July 2009.

[5] S. Faris, “Novel 3-D Stereoscopic Imaging Technology,” in *Stereoscopic Displays and Virtual Reality Systems, SPIE vol. 2177* , San Jose, California, 1994.

[6] D. Katzmaier, “4K TVs with passive 3D: Finally, a good use for all those pixels,” 6 February 2014. [Online]. Available: https://www.cnet.com/news/4k-tvs-with-passive-3d-finally-a-good-use-for-all-those-pixels/. [Accessed January 2021].

[7] “Illustrated 3D Movie List,” [Online]. Available: www.3DMovieList.com.

[8] A. J. Woods, “Crosstalk in stereoscopic displays: a review,” *Journal of Electronic Imaging,* vol. 21, no. 4, 2012.

[9] A. J. Woods, “Crosstalk in Stereoscopic Displays (PhD Thesis),” Curtin University, Perth, Australia, 2013.

[10] M. A. Weissman and A. J. Woods, “A simple method for measuring crosstalk in stereoscopic displays,” in *Stereoscopic Displays and Applications XXII, Proceedings of Electronic Imaging, SPIE Vol. 7863*, San Francisco, California, 2011.

Author Biography

Andrew Woods is an Associate Professor at Curtin University where he manages the HIVE visualisation facility and a Research Engineer at the Centre for Marine Science & Technology. He specialises in visualisation, stereoscopic 3D imaging, 3D reconstruction, 3D cameras and displays, video electronics, underwater vehicles (ROVs), and engineering software development, with applications in offshore oil and gas, and maritime archaeology. He has BEng and MEng degrees in electronic engineering and his PhD was on the topic of crosstalk in stereoscopic displays.

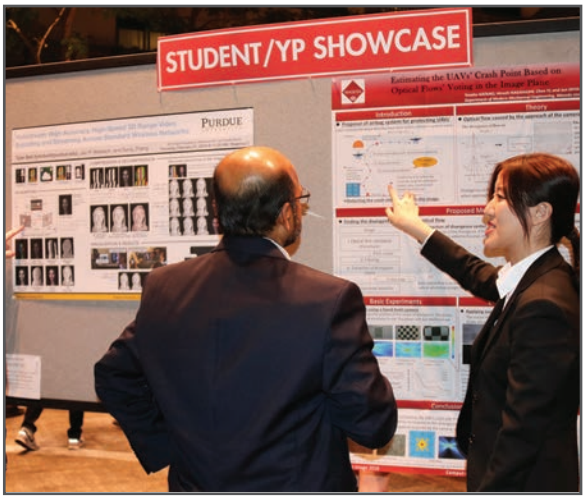
JOIN US AT THE NEXT EI!

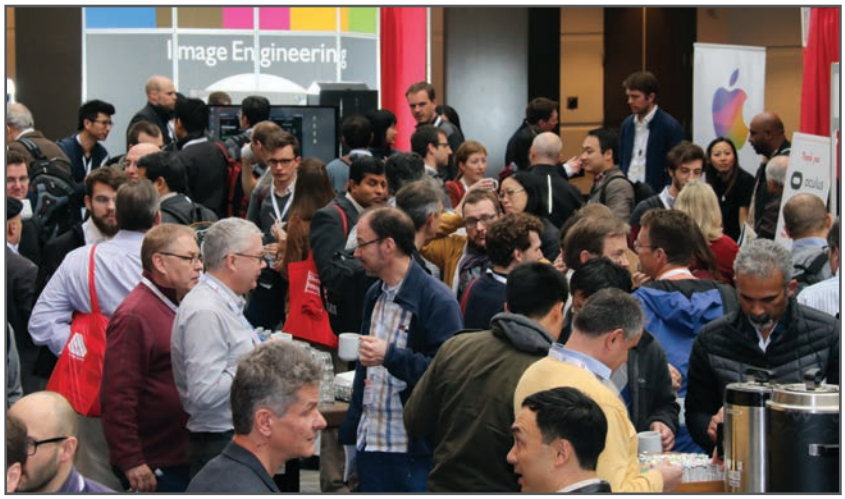
IS&T International Symposium on

Electronic Imaging

SCIENCE AND TECHNOLOGY

Imaging across applications . . . Where industry and academia meet!





• SHORT COURSES • EXHIBITS • DEMONSTRATION SESSION • PLENARY TALKS •
• INTERACTIVE PAPER SESSION • SPECIAL EVENTS • TECHNICAL SESSIONS •

www.electronicimaging.org

IS&T
imaging.org